National Aeronautics and Space Administration

Boundary Layer Measurements from Aura TES v05 water vapor retrievals

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ABSTRACT

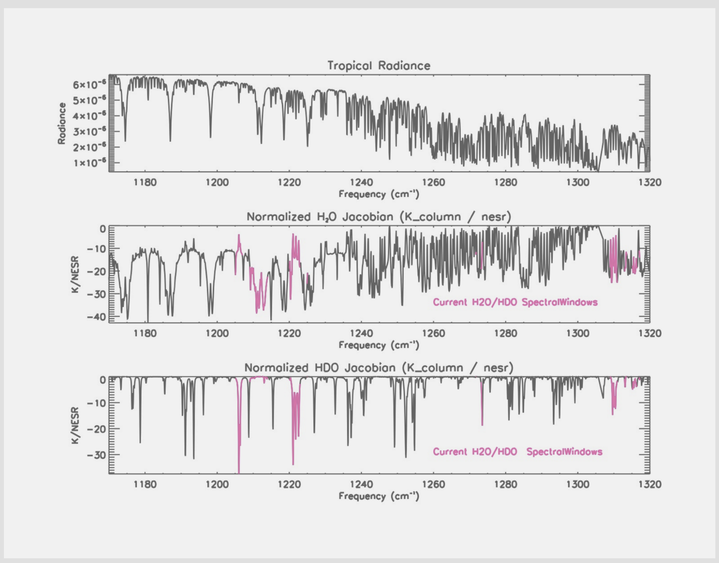
A recent development for the EOS Aura Tropospheric Emission Spectrometer (TES) is a wide band retrieval (1170 to 1330 cm^{-1}) to jointly estimate the mixing ratios of several species, including HDO, H_2O, CH_4, and N_2O. This new retrieval dramatically improves the vertical resolution in the lower troposphere for water vapor. In this study, TES v05 water vapor retrievals are used to infer the top of the mixed layer.

New TES Version 5 Retrievals

The TES instrument is an infrared, Fourier Transform spectrometer covering the spectral range from 650 to 3050 cm^{-1} with an apodized spectral resolution of 0.1 cm^{-1} in nadir pointing [Beer et al., 2001].

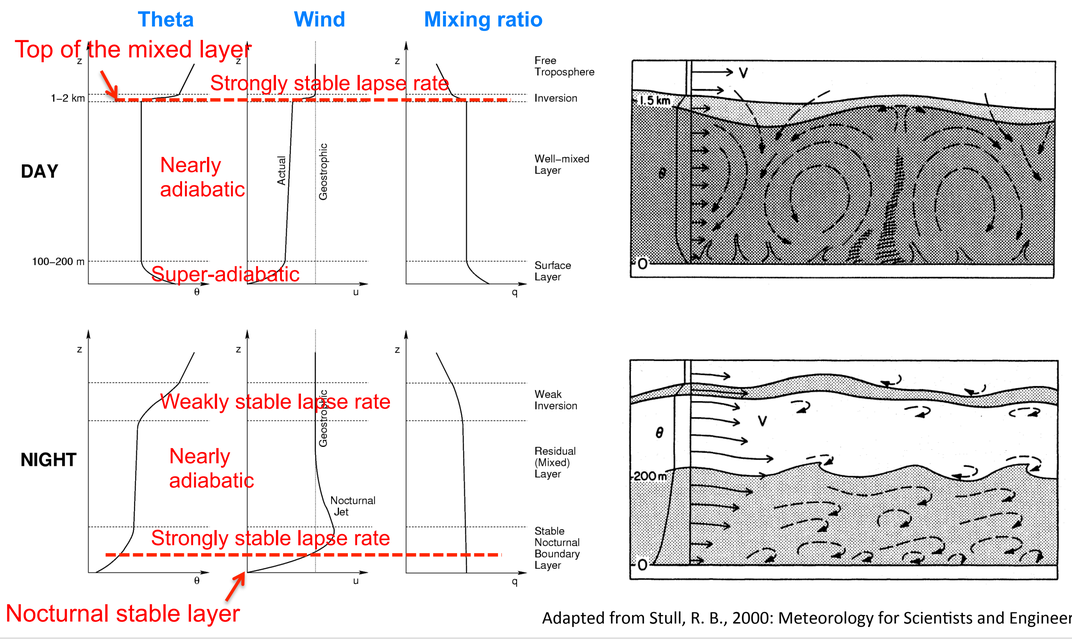
V04 retrieval: Limited vertical resolution due to small spectral windows (magenta) used in retrieval. Small spectral windows previously needed in order to minimize interference from other trace gases (Worden et al., 2004, and Worden et al., 2006).

New V05 retrieval now uses entire spectral region between 1170 and 1330 cm^{-1} to jointly estimate HDO, H_2O, CH_4, and N_2O. Joint retrieval required to minimize radiative interference. See the figure below from Worden et al. [2011].



Boundary Layer Structure: identify top of the mixed layer from maximum vertical gradient in water vapor.

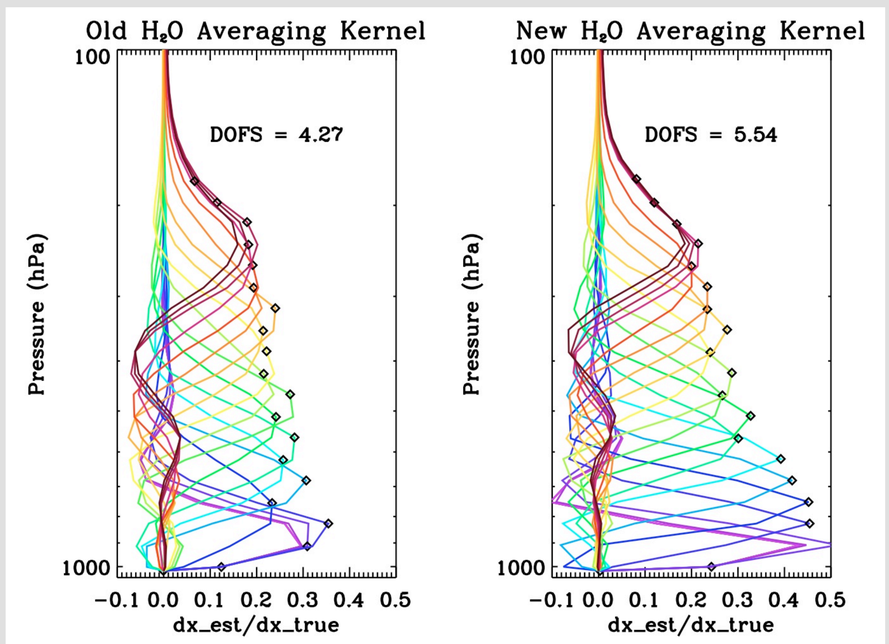
Example vertical distributions of theta, wind, and mixing ratio for typical daytime (convective) and nighttime (stable) scenarios



Adapted from Stull, R. B., 2000: Meteorology for Scientists and Engineers

TES increased sensitivity in the PBL:

The V05 retrieval yields greater vertical resolution of water vapor in the lower troposphere and planetary boundary layer (PBL). This is indicated by the sharpness of individual TES averaging kernel rows, as shown below [Worden et al., 2011]:



A priori Constraint from GMAO GEOS-5

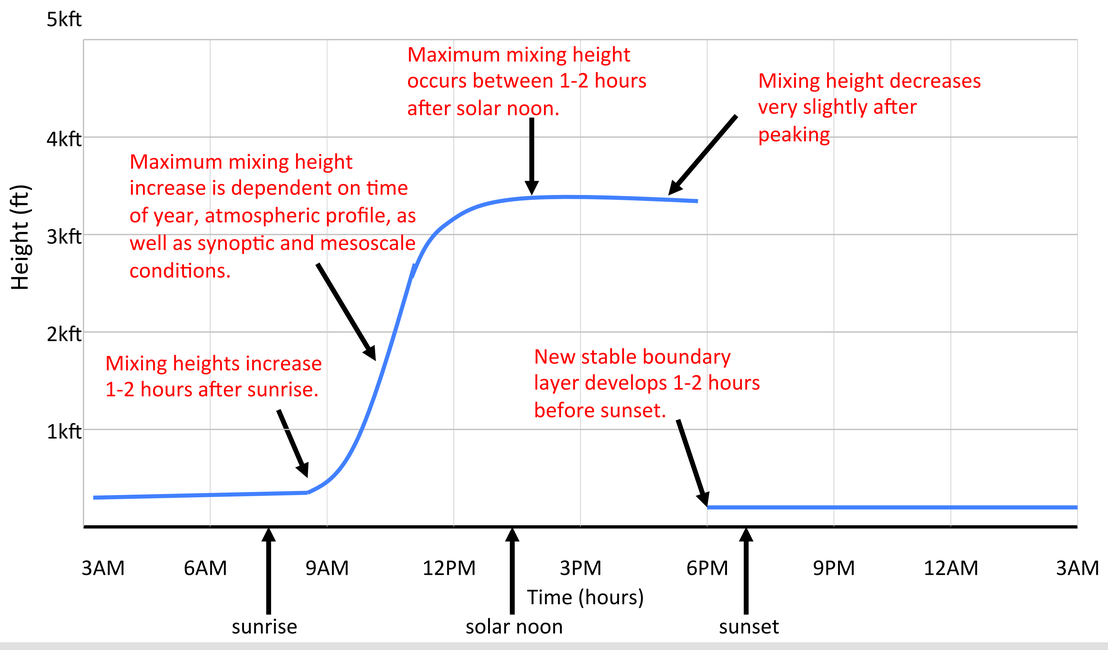
The TES V05 a priori constraint is H2O and TATM from GMAO GEOS-5.2. GEOS-5 assimilates a wide range of operational satellite retrievals, radiosonde data and other measurements [Rienecker et al., 2007]. Radiosonde data are strong constraints on the thermal structure and winds throughout the troposphere, with an emphasis on continental regions where the observing network is denser. Space based observations include the High Resolution Infrared Sounders (HIRS) and Advanced Microwave Sounders (AMSU) instruments on NOAA's operational sounders, which directly constrain temperature and moisture. GEOS-5 includes a direct assimilation of radiances from AMSU and HIRS in a three-dimensional variational assimilation, as well as radiances from the Advanced Infrared Sounder (AIRS) and AMSU instruments on NASA's EOS-Aqua platform [Zhu and Gelaro, 2007].

Time Dependent Height of the Mixed Layer

It is expected that, in the Aura ascending orbit (equator-crossing near 1:30 pm local time), the mixed layer should be close to its maximum height, as shown in the illustration below from Blaes et al. [2012].

Idealized Diurnal Mixing Height Curve

The idealized mixed layer height cartoon below highlights the relationship of the mixing height with the solar cycle.



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Boundary Layer Measurements from Aura TES v005 water vapor retrievals

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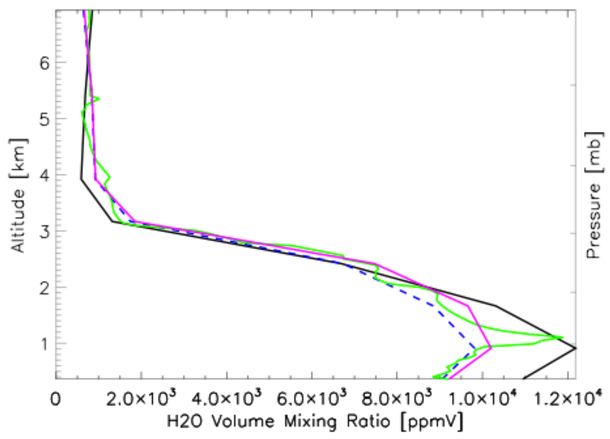
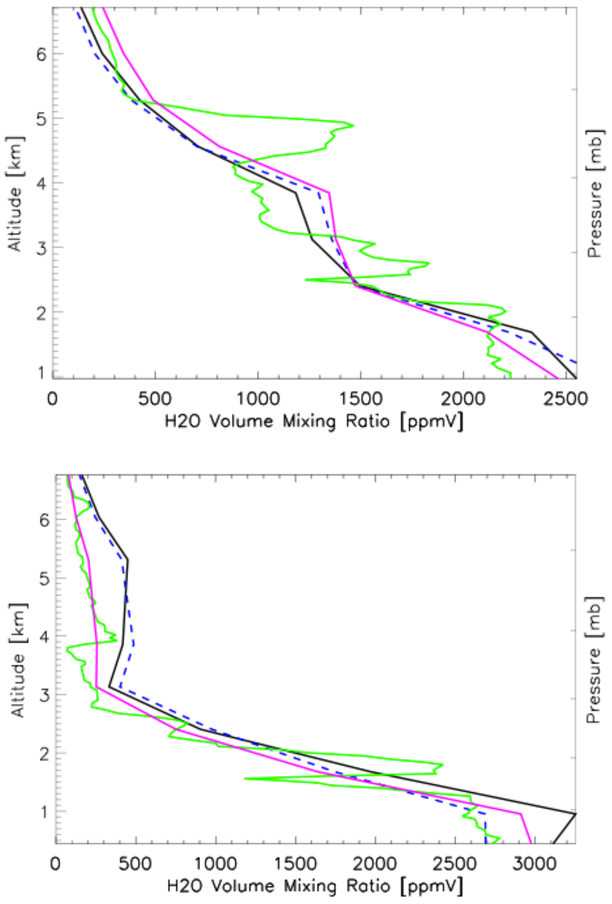
Comparisons between TES and radiosondes

For purposes of evaluating the quality of TES version 5 water vapor retrievals, the most readily available correlative data are provided by radiosondes. The TES averaging kernel has been applied to the radiosonde profiles. The disadvantage of radiosondes is the spatial mismatch between the satellite retrieval footprint (8 km by 5 km for TES) and the radiosonde data (a vertical profile of in-situ measurement with no horizontal information). To overcome this problem, we select test cases with close spatial coincidence (< 10 km) and timing within 2 hours. Also cloud optical depth is considered, usually selecting comparisons with retrieved optical depth less than 0.1.

TES comparison with ARM SGP radiosondes

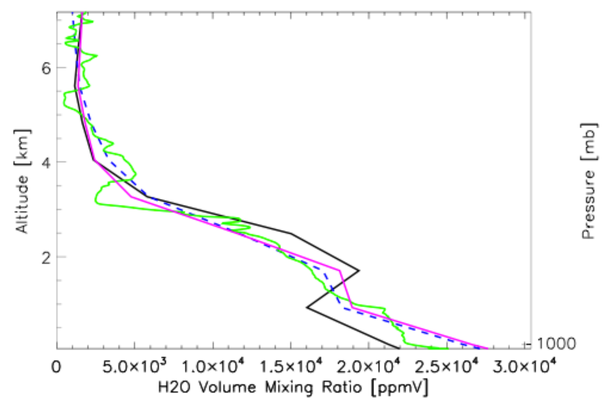
In 2006, Sippican (Mark II) radiosondes were launched from the DOE Atmospheric Radiation Measurement Southern Great Plains site (ARM SGP) in Oklahoma in coordination with TES special observations [F. Schmidlin, pers. comm.]. Below are shown some of the comparisons: radiosonde water (green), radiosonde with TES averaging kernel (magenta), TES retrieval (black), and GMAO GEOS-5 (blue dashed line). Plots are (top to bottom) TES run 3286 on 27 Jan 2006, TES run 3321 on 10 Feb 2006, and TES run 3326 on 12 Feb 2012. In each case, the water vapor mixing ratio drops rapidly between the TES retrievals at 908 hPa and 825 hPa, and we infer from TES that the top of the mixed layer is between these two levels (1-2 km MSL).

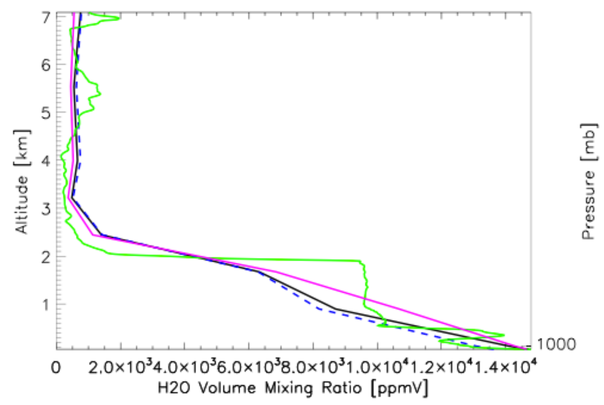




TES comparison with WAVES

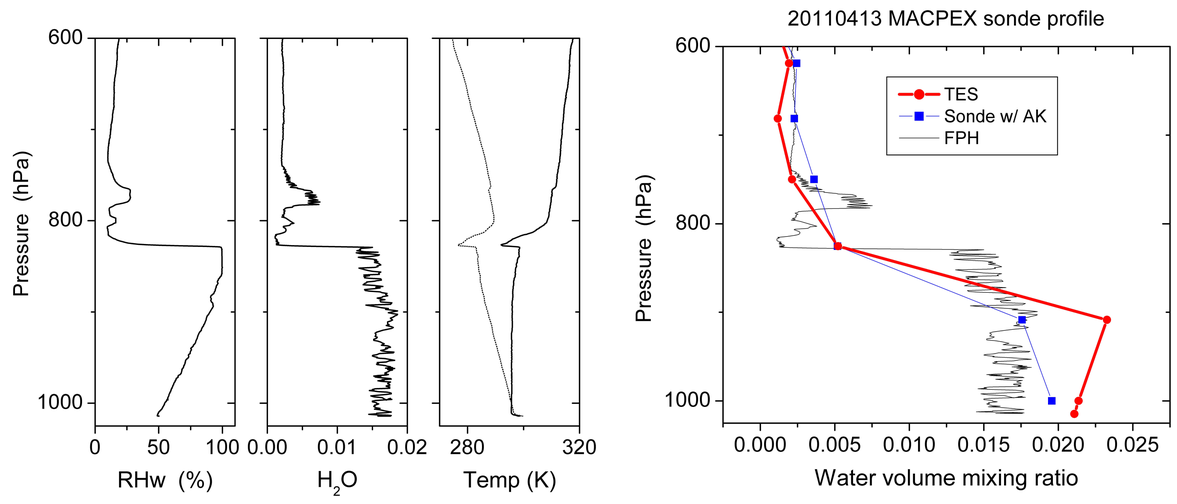
In the summer of 2006, the Water Vapor Validation Experiments (WAVES) took place in Beltsville, MD. On 11 July and 12 August 2006, radiosonde launches were coordinated with TES transect special observations (runs 4477 and 4803, respectively). The top of the mixed layer is at approximately 2 km MSL.





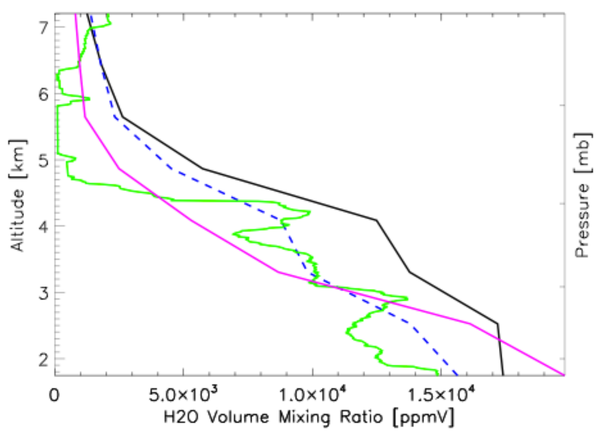
TES comparison with Frost-Point Hygrometer

On 13 April 2011, a radiosonde launch was coordinated with a TES transect special observation (run 12659) as part of the NASA Mid-Latitude Airborne Cirrus Properties Experiment (MACPEX) [D. Hurst, pers. comm.]. The figure below shows (left panel) relative humidity from a Humirel sensor on an iMet sonde, (panel 2) water vapor from a Frost-Point Hygrometer (FPH), and (panel 3) temperature and potential temperature. All of the in-situ measurements indicate the top of the boundary layer is at 829 hPa. In the 4th panel on the far right is shown the nearest good TES retrieval (red line). The seven retrieval levels in the lower troposphere (red symbols) are spaced relatively far apart, but the gradient between PBL and free troposphere is reproduced in the TES retrieval.



TES comparison with Ticosonde (Costa Rica

On 1 Feb 2006, a radiosonde launch from San Jose, Costa Rica, was coordinated with a TES transect special observation (run 3296). This was carried out as part of Ticosonde (Selkirk et al.) associated with the CRAVE field mission. The elevation of San Jose is 1.2 km. Although water is variable, we infer the top of the mixed layer between 4 and 5 km MSL.



Summary

- **TES V005 water vapor has enhanced sensitivity in the planetary boundary layer.**
- **In this preliminary study, several comparisons have been made with radiosonde profiles. TES V005 retrievals can identify the top of the mixed layer, particularly when there is a contrast between humid boundary layer and dry free troposphere.**
- **Future Work: analyze radiosonde comparisons from SHARP, Discover-AQ and other field missions with coordinated radiosonde launches.**

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